AAPG Datapages/Search and Discovery Article #90174 CSPG©2014 CSPG/CSEG/CWLS GeoConvention 2012, (Vision) May 14-18, 2012, Calgary, AB, Canada

On the Road to 3D Seismic Imaging of Massive Sulphide Deposits in a Sediment-Hosted Permafrost Environment

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Summary

In this report, we investigated the feasibility of using seismic reflection techniques for imaging sediment-hosted massive sulphide deposits in a permafrost environment. Synthetic seismic data was generated using a 2D finite difference elastic wave code which enabled us to see how seismic wavefields are affected by massive sulphide deposits at depths between 250-500m. Our 2D geology model, including sulphides, barite and sediments, was used as input to the finite difference program. Strong surface waves due to high background velocities (4500m/s) resulted in a low signal to noise ratio. Removing the strong surface wave can be achieved through f-k filtering provided receiver spacing is no larger than 4-5 meters. We also found that by using 3D survey designs, imaging the orebody can be optimized.

Introduction

Synthetic seismic data for this study was generated using a 2D finite difference elastic wave modeling method which enabled us to study the seismic character of massive sulphide structures in sedimentary host rock. P-wave velocities (Vp) and densities for the different lithologies in the model were obtained through statistical analysis of several logged boreholes. Shear wave velocities (Vs) were calculated using Poisson's ratio. Vp/Vs ratios are highly variable and unique often due to the irregular mineral composition of the rock (Schmitt et al., 2003). Using an elastic modeling program, we can model both p- and s- waves which will give a more accurate seismic wavefield response.

Lithology	Mean Vp(m/s)	Mean Density	Poisson Ratio	Mean Vs(m/s)
Sediment/Permafrost	4496	2.71	0.35	2160
Sulfides	5592	3.84	0.20	3424
Barite	4612	3.95	0.20	2824

Table 1: Rock physics data used as input for the 2D geology model of sediment hosted massive sulphide deposit.

Two sulphide deposits and a barite lens were the reflective targets in the model (Figure 1). The acoustic impedance differences between all the lithologies are greater than 2.5 x 10^5 g/cm^{2}s, a minimum value for strong reflections (Salisbury et al., 1996).This study is unique in that it is the first time elastic wavefield modeling is applied to target sediment-hosted massive sulphide deposits. The presence of the dense barite is also unique to this model. Our model is similar to the well-known Pine Point carbonate/shale hosted massive sulphide deposit in NWT (see Reed, 1993).

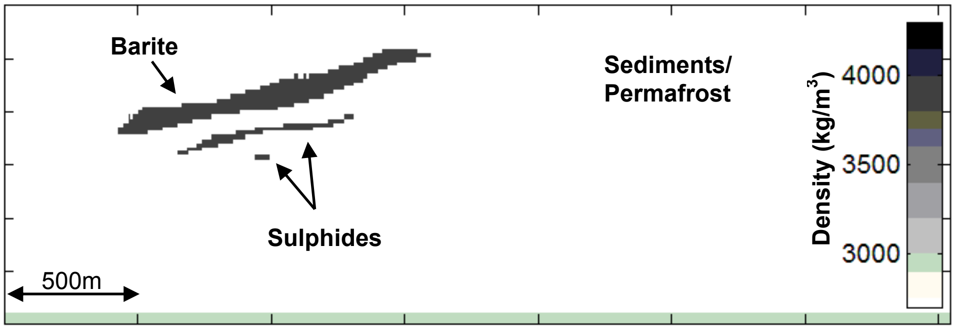

Figure 1: The 2D geology model displaying density values. Models for Vp and Vs were also created and used as input for the elastic finite difference program. Our model includes sulphides, barite and a sediment host rock. No vertical exaggeration.

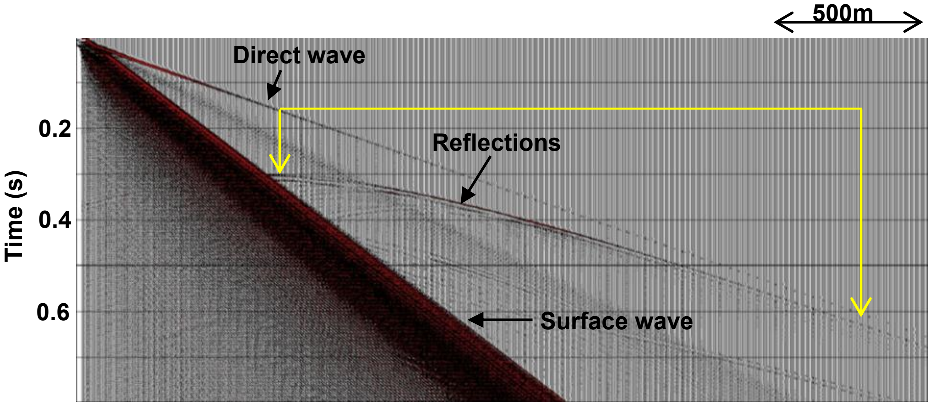

Figure 2: A vertical component synthetic seismogram with a strong surface wave, direct wave and reflections (relative true amplitudes). The optimum offsets window for shallow high density targets is indicated by yellow arrows and is 600-2000m.

Data processing and survey design techniques targeted at removing or avoiding the surface wave are discussed in the next section. Implications for 3D survey designs, in particular using an optimum offset window, a reflection seismic technique developed and tested by GSC (Hunter et al., 1984) are discussed in the next sections.

Theory and Method

The synthetic seismic data was generated using a 2D elastic finite difference code (Bohlen, 2002). Three models, Vp, Vs and density, were generated using statistical analysis of borehole logs, and used as input to the finite difference program. An example of a synthetic shot record is shown in Figure 2. We generated multiple shot records and 726 receivers were spread along the surface of the model at 4m increments. We subtracted background response seismograms from our complete seismograms to obtain shot records with only reflections from barite and sulphides (Figure 3). Once the surface waves and direct waves were removed, the data were processed using VISTA Seismic Data Processing software. Full processing was performed, including common midpoint (CMP) binning, velocity analysis, CMP stack and migration. The final migrated stack (Figure 4) highlights the strong reflections from both the sulphides and the barite. Their geometries and locations are well defined.

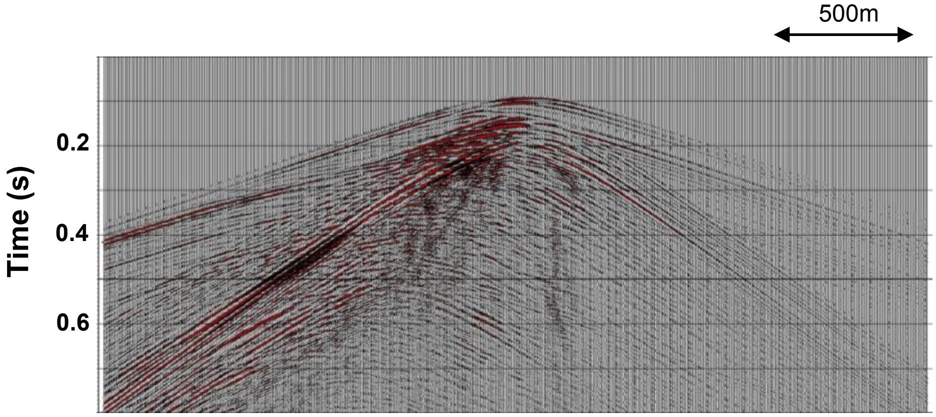

Figure 3: A synthetic shot record with the direct and surface waves subtracted- the vertical component of the elastic wavefield. All energy in the seismogram is from the reflectors in the model.

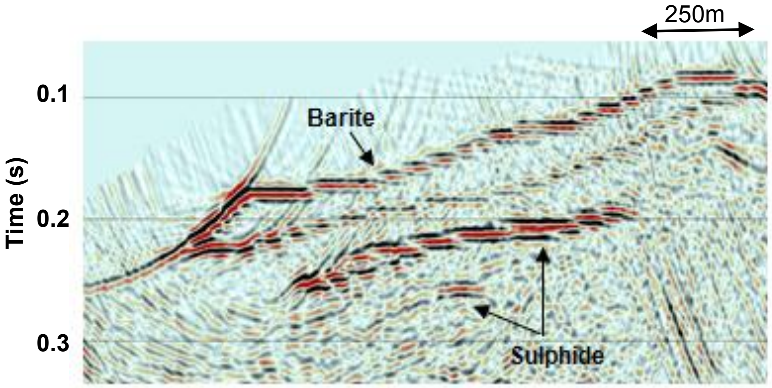

Figure 4: The first 300ms of data of the migrated stacked section. Arrows indicate reflections from sulphides and barite.

In data processing, f-k filtering is often used to remove strong surface waves. We tested various receiver spacings for our model and found that in order to obtain data that is not spatially aliased 4 to 5 meter spacing is required. With reference to Figure 2, we can use the optimum offset window for 3D seismic survey designs (Figure 5) where reflections from the target are not obstructed by surface and direct waves (Hunter et al., 1984).

Conclusions

This study showed that using 2D elastic finite difference methods to image sediment-hosted massive sulphide deposits is effective. The success of imaging the target structures depends on the effective removal of the strong surface waves. The presence of strong surface waves in permafrost environments can be dealt with through processing if trace spacing is fine enough (4-5m). Optimal imaging of the sulphide orebody can be further achieved by using 3D survey designs. In such 3D designs, optimum offset windows are used such that reflections from the target are seen with minimal interference from the surface and direct waves. The receivers can be processed on adjacent survey lines to obtain additional, low fold, lateral coverage.

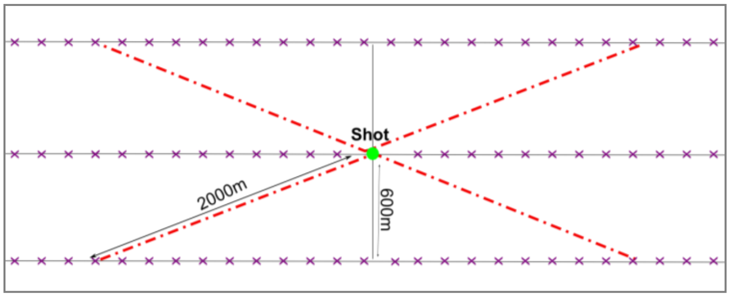

Figure 5: Optimum Offset survey design for shallow dense targets showing three survey lines with receivers (purple crosses). For a normal 2D survey on the center line you can process receivers on the adjacent lines that lie in the optimum offset window. The minimum and maximum offsets are 600m and 2000m respectivley (refer to Figure 2).

The data we generated in this study provides insight into the processing sequences and survey planning needed for a 3D seismic survey aimed at detecting massive sulphides at depths of 250-500m.

Acknowledgements

Funding for this work was supported by NSERC

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